

Chapter 2

Compasses

Introduction

The compass is the best known and most widely used of all navigational instruments. It would be almost impossible to obtain precise information on headings and directions without the compass.

There are two types of compasses in use. The *gyrocompass* is the compass that is used the most aboard ship. The *magnetic* compass is used as a backup because it requires no electricity to operate. This chapter will explain the operation and use of each type of compass and its related equipment.

Objectives

The material in this chapter will enable the student to:

- Describe the components of the magnetic and gyroscopic compasses.
- Identify and correct for compass errors.
- Explain the procedure used to determine magnetic compass error.
- Record entries in the Magnetic Compass Record Book.
- Describe the process of swinging ship, conducting compass sensibility tests, and filling out the compass deviation card.
- Determine gyrocompass error.

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The Magnetic Compass

Introduction

Before we proceed to determine the proper compass heading to steer, we must first learn about the workings of the magnetic compass.

To enable you to understand the principles, we will explore the properties of magnetism.

Magnetism

Magnetism is a phenomenon of nature known only by its effects. It appears as a physical force between two objects of metal, at least one of which has been previously magnetized and has become a magnet.

Definition

A magnet is a metallic element that has the property for attracting iron and producing a magnetic field around itself. For the purpose of illustration, this magnetic field is usually pictured as lines of force.

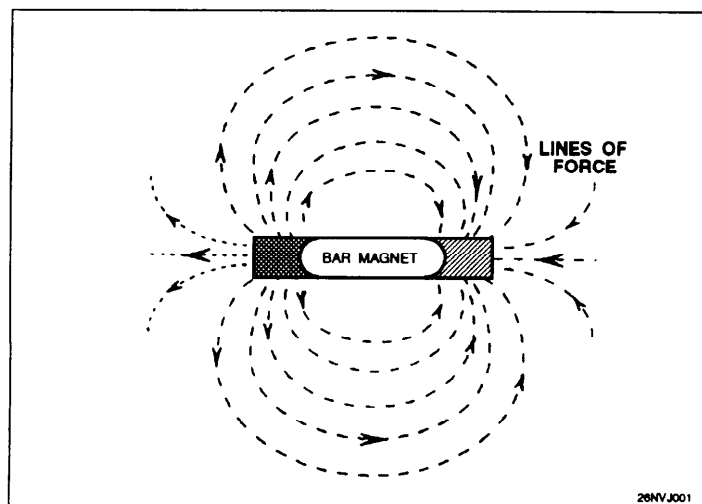


Figure 2-1. Magnetic lines of force.

Types of Magnetism

There are two types of magnetism: *permanent* and *induced*. A metal bar having permanent magnetism will retain its properties when it is removed from a magnetic field.

A metal bar having induced magnetism, however, will **lose** its properties when it is removed from the same field

Earth's Magnetic Field

Introduction

Earth has magnetic properties and can be thought of as having a powerful magnet near its center (see fig. 2-2). The lines of force radiate and may be detected on the surface.

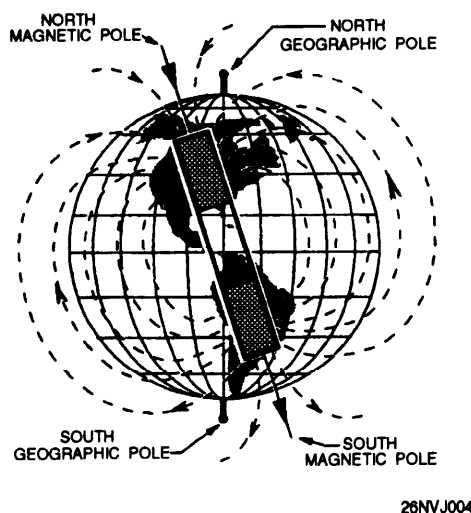


Figure 2-2. Earth's magnetic field.

This internal magnet is **not** aligned with Earth's axis. This results in the magnetic poles being in different locations than Earth's poles. At Earth's surface, lines of force become magnetic meridians having horizontal and vertical components. These components will be discussed in the next topic, Variation.

Law of Magnetism

There are certain characteristics of magnetism that are important to remember. Every magnet has two poles: a north pole (blue) and a south pole (red). Each pole has opposite characteristics and they each follow the Law of Magnetism:

"OPPOSITES ATTRACT; LIKES REPEL"

A north pole attracts a south pole but it repels another north pole. This law is of importance to you because it will help you understand the relationship between the magnetic compass and the magnetic properties of Earth.

How to Determine Local Variation

Background

While standing the QMOW, you will routinely be tasked with determining variation. This is a simple procedure using simple mathematics and the chart's compass rose. Use the following steps to find your local variation.

Step	Action
1.	Locate the compass rose nearest to the area in which the ship is operating.
2.	Locate the variation and annual increase/decrease from the center.
3.	Locate the year from the center of the compass rose.
4.	Subtract the year indicated from the current year.
5.	Multiply the number of years times the annual change.
6.	Add the sum (or subtract if decreasing) from step No. 5 to the variation in the center of the compass rose.
7.	Round the total off to the closest $\frac{1}{2}^{\circ}$.

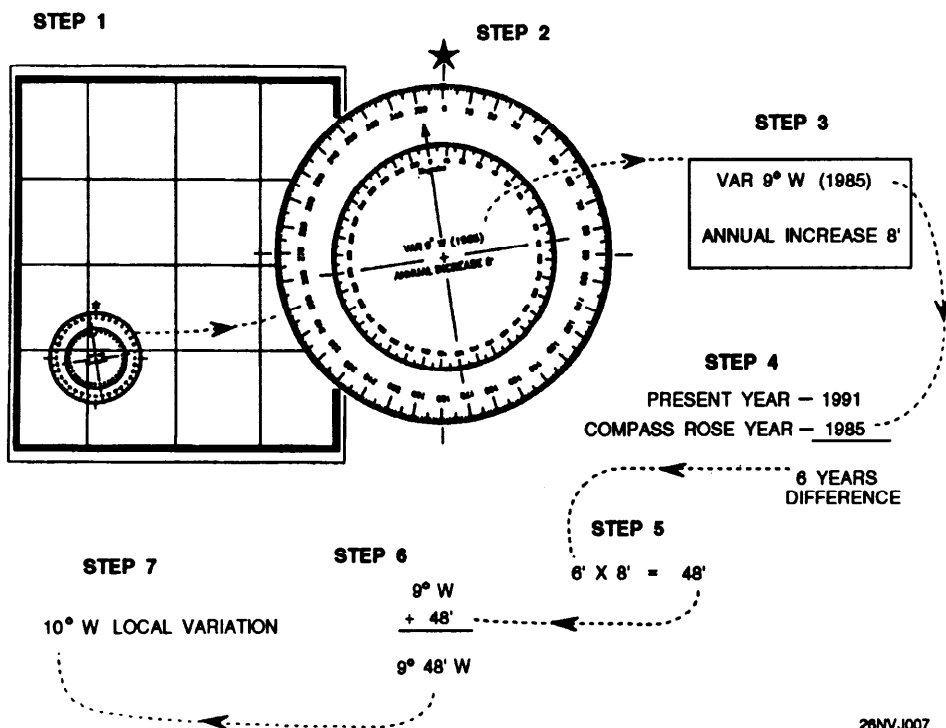


Figure 2-5. Steps followed to determine variation.

Standard and Steering Compasses

Compasses are REQUIRED

The Chief of Naval Operations requires that each self-propelled ship and service craft of the United States Navy be equipped with one or more magnetic compasses suitable for navigation.

Except for modern nuclear-powered submarines, all ships and craft, regardless of size or classification, must have a magnetic steering compass at the primary steering station.

Steering Compass

Many ships carry more than one magnetic compass. The primary magnetic compass is called the *steering compass*. It is normally located on the centerline in the ship's pilothouse (except aboard aircraft carriers), where it can best be seen by the helmsman. The readings from the steering compass are labeled "*per steering compass*" (*PSTGC*).

Standard Compass

If a ship has two magnetic compasses, the second compass is called the *standard compass*. The ship's standard compass is normally located on the ship's centerline at the secondary conning station. The readings from the standard compass are expressed as "*per standard compass*" (*PSC*).

Note

The readings from the ship's gyrocompass are "*per gyrocompass*" (*PGC*). Courses and bearings by these compasses must be carefully differentiated by the abbreviations.

Cautions

A magnetic compass cannot be expected to give reliable service unless it is properly installed and protected from disturbing magnetic influences. Certain precautions must be observed in the vicinity of the magnetic compass.

- If possible, a compass should not be placed near iron or steel equipment that will be moved frequently. Thus, a location near a gun, boat davit, or boat crane is not desirable.
- The immediate vicinity should be kept free of sources of magnetism, particularly those of a changing nature.
- When possible, no source of magnetism should be permitted within a radius of several feet of the magnetic compass.

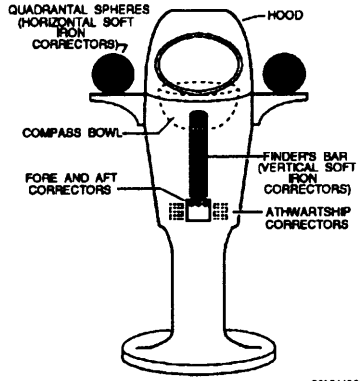
Magnetic Compass Operation and Components

Operation

The operation of a magnetic compass is very simple and can be stated as follows: *"A small bar magnet freely suspended in the magnetic field of Earth will always align itself parallel to the lines of force of that field and thus will establish a direction."*

Components

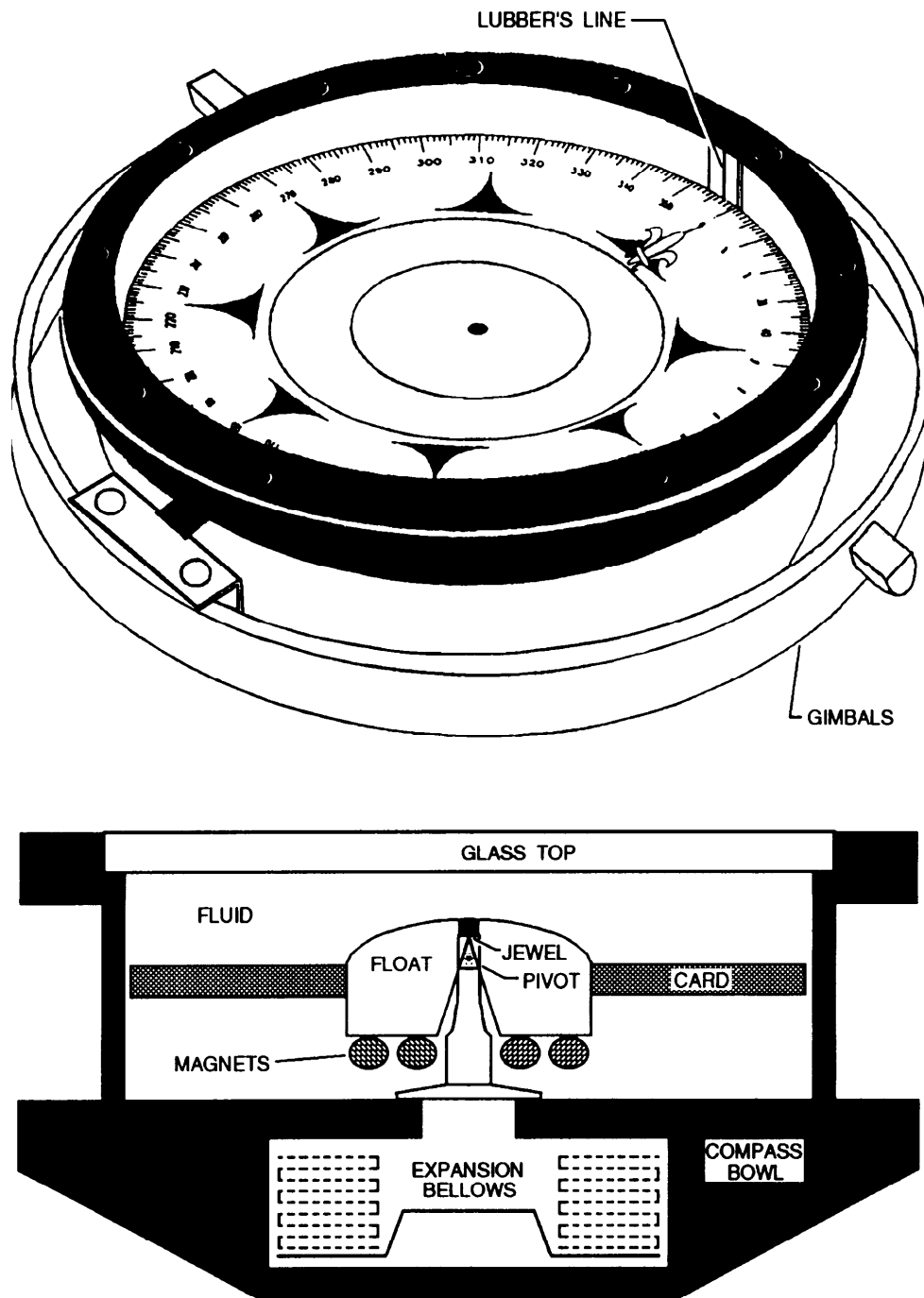
Use the following table, figure 2-6, and figure 2-7 to learn the parts of a magnetic compass.

Part	Function
Card	The card is an aluminum disk graduated in degrees from 0 to 359. It has a jeweled bearing that rides on a hard, sharp pivot point.
Bowl	The card is supported by the bowl. A lubbers line is marked on the bowl and is used as visible index. The bowl is filled with Varsol to dampen overswings by the card. An expansion bellows in the lower bowl serves to allow expansion of the liquid with temperature changes.
Magnets	Several bar magnets are used to correct and align the compass.
Gimbals	The bowl has two pivots that rest in a metal ring, which also has two pivots resting in the binnacle. This arrangement (gimbals) permits the compass to remain level despite the motion of the ship.
Binnacle	<p>The binnacle serves as a housing for the compass. It is made of a non-magnetic material. It also serves as a housing for the compass correctors: magnets, flinders bar, and quadrantal spheres. A lighting system is normally installed.</p>  <p>Figure 2-6. Compass binnacle</p>

Magnetic Compass Operation and Components, Continued

Components

The following illustrations should help you visualize the working parts of a basic magnetic compass.



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Figure 2-7. Parts of a magnetic compass.

Magnetic Compass Error

Introduction Before we use a magnetic compass aboard a ship, we must first correct for the magnetic influences that make the compass deviate from true or geographic north.

The first influence is **variation**, which we have already covered. The second is **deviation**.

Deviation Deviation may be defined as the amount that the compass is deflected from the magnetic meridian because of the effects of the ship's iron. This is where **permanent** and **induced** magnetism come in to play.

Permanent Magnetism Also known as hard-iron magnetism, permanent magnetism is created in the ship's structure during the building process. The ship's structure gains its own unique magnetic field based on the angle that the keel was laid.

Induced Magnetism Also known as soft-iron magnetism, induced magnetism varies according to the intensity of the component of Earth's field in which it was induced.

Compass Error The amount of deviation **varies** as the ship changes course. The ship's magnetic effects may be corrected by the proper placement of various correctors.

The **process** of correcting for deviation error is called **swinging ship**. The navigator and QM gang will swing the ship through 360 degrees, stopping each 15 degrees and comparing the compass heading against a properly functioning gyrocompass. The results are recorded on the magnetic compass deviation table.

Example: While swinging ship and steady on course 015° by gyro, the magnetic compass reads 016°. It should read 015°; the 1° difference is the amount of deviation. In this case, it is labeled westerly deviation 1.0° W.

Next The next topic deals with the magnetic compass deviation table. From there we will look at degaussing, and then you will learn how to perform compass calculations to correct for variation and deviation.

Magnetic Compass Deviation Tables

Purpose

The purpose of the magnetic compass deviation tables, commonly referred to as "deviation tables," is to provide a means of knowing the deviation of the magnetic compass for any heading. This information is crucial to safe navigation if the gyrocompass fails.

Table Composition

The figure on the right is an example of a deviation table. The top portion of the table contains the name of the ship, location of the compass (pilothouse), binnacle type, and compass type.

The middle section of the table contains the ship's heading and deviation data.

Example: You want to steer course 090° magnetic. By inspecting the table for ship's heading 090°, you'll notice that the deviation is equal to 1.0° West with DG OFF (DG is an abbreviation for degaussing) and 1.5° West with DG ON. To make good 090°, you would have to actually steer course 091°.

The bottom portion of the table contains information on magnet and flinders bar placement that corrects for excessive deviations.

MAGNETIC COMPASS TABLE					
NAVY FORM 3120-1					
U. S. S. <u>CLEVELAND</u>			NO. <u>LPD-7</u>		
<input checked="" type="checkbox"/> PILOT HOUSE	<input type="checkbox"/> SECONDARY CORNING STATION	<input type="checkbox"/> OTHER _____			
BINNACLE TYPE: <input checked="" type="checkbox"/> NAVY STD		<input type="checkbox"/> OTHER _____			
COMPASS <u>7 1/2"</u> MAKE <u>LIONEL</u>		SERIAL NO. <u>13613</u>			
TYPE COILS <u>K</u>		DATE <u>19 SEP 1984</u>			
READ INSTRUCTIONS ON BACK BEFORE STARTING ADJUSTMENT					
SHIPS HEAD MAGNETIC	DEVIATIONS		SHIPS HEAD MAGNETIC	DEVIATIONS	
	DG OFF	DG ON		DG OFF	DG ON
0	1.5W	0.0	180	0.0	0.5E
15	0.5W	0.5E	195	0.5E	1.5E
30	0.0	1.0E	210	1.5E	2.0E
45	0.0	0.5E	225	2.5E	2.5E
60	0.0	0.0	240	3.0E	3.0E
75	0.5W	0.5W	255	2.5E	2.5E
90	1.0W	1.5W	270	1.5E	1.0E
105	2.0W	2.0W	285	0.0	0.0
120	3.0W	1.5W	300	0.5W	1.0W
135	2.5W	0.5W	315	2.0W	1.5W
150	2.0W	0.5W	330	2.5W	1.0W
165	1.0W	0.0	345	2.0W	0.5W
DEVIATIONS DETERMINED BY <input type="checkbox"/> SUNS AZIMUTH <input checked="" type="checkbox"/> GYRO <input type="checkbox"/> SHORE BEARINGS					
B. <u>2-4"</u> MAGNETS RED <input checked="" type="checkbox"/> FORE AT <u>15</u> " FROM COMPASS CARD					
<input type="checkbox"/> AFT					
C. <u>0</u> MAGNETS RED <input type="checkbox"/> PORT AT _____ " FROM COMPASS CARD					
<input type="checkbox"/> STBD					
D. <u>2-5"</u> <input checked="" type="checkbox"/> SPHERES AT <u>12</u> " <input type="checkbox"/> ATHWART-SHIP <u>0</u> ° <input type="checkbox"/> CLOCKWISE					
<input type="checkbox"/> CYLS <input type="checkbox"/> SLEWED <input type="checkbox"/> CTRL CLKWISE					
HEELING MAGNET <input type="checkbox"/> RED UP <u>13.6</u> " FROM COMPASS CARD <input checked="" type="checkbox"/> BLUE UP					
FLINDERS BAR <input checked="" type="checkbox"/> FORE <u>12</u> "					
<input type="checkbox"/> AFT					
<input checked="" type="checkbox"/> LAT <u>23° 24' North</u>			<input checked="" type="checkbox"/> LONG <u>130 39' East</u>		
<input type="checkbox"/> M			<input type="checkbox"/> Z		
SIGNED (Adjuster or Navigator) R. E. FERGUSON			APPROVED (Commanding) J. B. RIDGE CAPT USN		

Figure 2-8. Magnetic compass deviation table.

How to Determine Deviation

Information

As you learned in the last topic, the deviation tables contain information on the deviation for headings. The deviation table must be updated annually and posted on or near the magnetic compass. Follow the steps in the step action table to determine the deviation and magnetic course to steer.

Example: Refer to figure 2-8. Your ship is on course 090° T, the gyro fails and the OOD now wishes to make good course 117° (magnetic course) by magnetic compass. Find the proper deviation from the magnetic compass deviation table and recommend the correct magnetic course to steer to make 117° good. In this example we will assume that degaussing is turned OFF.

DETERMINING YOUR DEVIATION		
Step	Action	Example/Result
1.	Determine if degaussing is ON or OFF <div style="display: flex; justify-content: space-between;"> <div style="text-align: center;">If OFF ON</div> <div style="text-align: center;">Then Use left column Use right column</div> </div>	OFF
2.	In the deviation table, locate the course nearest your desired course.	The nearest course is 120
3.	Read the deviation	Deviation equals 3.0 W
4.	Apply the deviation correction to the ordered course	<p>RULE: Westerly deviation means that the compass reads less than it should. You must add W deviation to the magnetic course.</p> <p>Easterly deviation is opposite, you must subtract the deviation from the magnetic course to get your course to steer or "compass course."</p> <div style="margin-top: 10px;"> <div style="display: flex; justify-content: flex-end;"> <div style="text-align: right;"> Magnetic Course 117° Deviation $+ 3^{\circ} \text{ W}$ Compass Course 120° </div> </div> </div> <p>Because of the compass deviation you must steer compass course 120° to make magnetic course 117° good.</p>

The Shipboard Degaussing System

Purpose

When a ship is close to a magnetic mine or magnetic torpedo, the magnetic field of the ship actuates the firing mechanism and causes the mine or torpedo to explode. Degaussing is an electrical installation designed to protect ships against magnetic mines and torpedoes. The purpose of degaussing is to counteract the ship's magnetic field and establish a condition such that the magnetic field near the ship is, as nearly as possible, just the same as if the ship were not there.

Components

Shipboard degaussing installation consists of permanently installed degaussing coils, a control unit to control the coil current, and compass compensating equipment to prevent disturbances to the magnetic compasses by the magnetic field of the degaussing coils. Figure 2-9 illustrates the types of coils that are found on a typical degaussing installation.

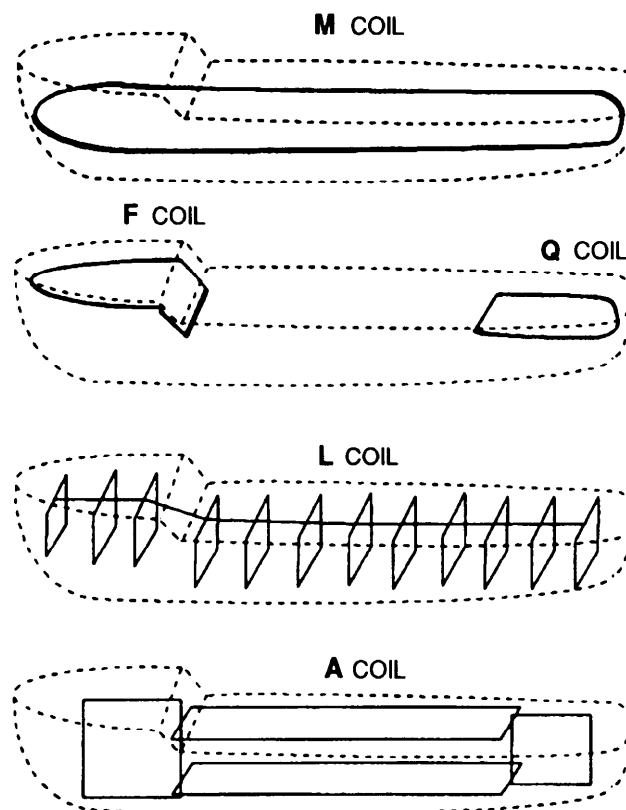


Figure 2-9. Typical degaussing coil layout.

The Shipboard Degaussing System, Continued

Degaussing Coils The degaussing coil is actually a large diameter electrical wire. As you might have guessed, when it is energized it produces an electromagnetic field.

The following table gives a description of each coil and its effect on the ship's magnetic field.

Coil	Description
A	The A, or athwartship, coil is made up of loops in vertical fore-and-aft planes. The function of the A coil is to produce a magnetic field that will counteract the ship's athwartship permanent and induced magnetism.
F	The F, or forecastle, coil encircles the up to the forward 1/3 of the ship. It is usually located just below the forecastle or uppermost deck. The function of the F coil is to produce a magnetic field that will counteract the ship's longitudinal permanent and induced magnetism.
L	The L, or longitudinal coil is made up of loops in vertical planes parallel to the ship's frames. The function of the L coil is to produce a magnetic field that will counteract the ship's longitudinal permanent and induced magnetism.
Q	The Q, or quarterdeck, coil encircles the after 1/3 of a ship. It serves the same purpose as the F coil.
M	The M, or main, coil encircles the ship in a horizontal plane, usually just below the waterline. The function of the M coil is to produce a magnetic field that will counteract the ship's vertical permanent and induced magnetism.

Degaussing and the Magnetic Compass

The deviation to the magnetic compass resulting from these currents is neutralized as much as possible by a procedure called compensation. The remaining deviations caused by the degaussing coils are observed and plotted on the left side of the deviation table.

Compass Error Calculations

Background

In navigational work, you have to develop the ability to quickly and accurately convert directions between true, magnetic, and compass (headings, courses, and bearings).

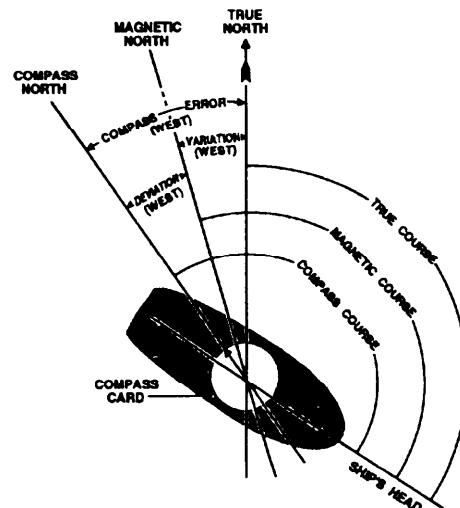
A heading or course is the same as an angle. It is the angle that the centerline of the ship or boat, or a line marked on a chart makes with some other reference line.

Reference

Three lines of reference have been established: the direction of true north, or the true meridian; the direction of magnetic meridian; and the direction of the north point of the compass. Ship's heading is the same. How you describe it depends on the reference point used.

There are three ways to name a course or heading:

- True heading
- Magnetic heading
- Compass heading



Comment

Whether you are determining courses the helmsman is to steer, obtaining bearings to be plotted on a chart, laying track lines on the chart, or recording courses in the Magnetic Compass Record Book, knowing how to apply variation and deviation comes into play. The big question is "how do we convert one to the other?" Practice is needed to perform this task. However, keep in mind that you first need to reason each step, until later when the process becomes habit.

Memory-Aids

Information

There are several sets of "memory-aids" available to assist you in performing compass calculations. The following simple phrases are designed to assist you in remembering how to convert from one heading expression to another and how to name errors.

Memory Aid Set 1		Memory Aid Set 2	
Can	= Compass	Timely	= True
Dead	= Deviation	Vessels	= Variation
Men	= Magnetic	Make	= Magnetic
Vote	= Variation	Distance	= Deviation
Twice	= True	Count	= Compass
At	= Add	At	= Add
Elections	= Easterly D and V	War	= Westerly D and V
If the Compass is Best the Error is West.		If the Compass is Least the Error is East.	

Meanings

The first set of aids were designed to help you remember the arrangement of the first letters of each word in the phrase. These are arranged representing the three ways of naming a direction (compass, magnetic, true) with the respective differences (deviation and variation) properly placed between them: (CDMVT) compass, deviation, magnetic, variation, true. The first letters in the words *at elections* stand for add east (subtract west), when converting the direction from compass to true. When converting in the opposite direction, the letters are reversed (TVMDC) and the memory aid "timely vessels make distance count at war" informs us to add west (subtract east) error when converting from true to compass.

The second set of memory aids deal with comparison of two compass headings to determine whether to call the difference east or west. If the comparison is between magnetic and compass, and compass is a greater number (best), the difference is west. The same comparison can be made between true and magnetic. In this case, magnetic is considered the same as compass.

Correcting: converting from compass course to a true course

Uncorrecting: converting from a true course to a compass course

How to Perform Compass Calculations

Preforming Calculations

The following table will allow you to visualize the steps necessary to perform compass calculations. The table is followed by several example exercises that should be completed before you move on to additional material.

Step	Action
1.	Write down the first letters from the phrase "Can Dead Men Vote Twice."
2.	Ordered course is 180°T; you want to find the compass course to steer. You already know what T is, so write it down.
3.	Let's say that the corrected variation from the center of the compass rose is 11°E.
4.	When uncorrecting, remember that you add westerly errors and subtract easterly errors. The variation is easterly, so subtract it from the true heading to find the magnetic heading.
5.	Next, from the deviation table, figure 2-8, find the value closest to 169°, interpolating as necessary; write it down.
6.	Remember, when uncorrecting you add westerly errors. $15 + 169 = 184$.

Closing

Now you can see that to head 180° true, you must steer 184° by this particular magnetic compass. In this example, we were uncorrecting (changing from true to compass). We could have used the same method to change from compass to true; but we must remember that when correcting, we add easterly and subtract westerly errors. With an understanding of these rules, we can now go on to applying the lessons learned to a functional part of a Quartermaster's job—recording entries in the Magnetic Compass Record Book. But first, complete the training examples on the next page.

Exercises

Instructions

Now that you have been shown how to perform calculations using the magnetic compass and its error, you need to practice these skills. The following problems give you one or more values; you are to fill in the blanks with the correct answer. Take your time and refer back to previous material to complete each exercise.

Exercise 1 Find the missing values.

C	D	M	V	T
022	4E	026	6W	

C	D	M	V	T
090	1.5W		3E	

C	D	M	V	T
210	1.5E			220

C	D	M	V	T
328		325		332

Exercise 2 Using the memory-aids "Compass Best, Error West" and "Compass Least, Error East," fill in the missing values.

Compass Course	Actual Compass Reading	Error
180	182	2W
225	229	
196	193	

True Course	Actual Gyro Reading	Error
339	337	
196	194.5	

Practical Application

Compass Comparison

Whenever a ship is under way it is necessary to compare the ship's compasses to make sure that they are operating properly. This is accomplished by using the compass calculations and checking the compasses against the true course.

Example

The following table represents an excerpt from the Magnetic Compass Record Book.

Date	Time	Latitude	Longitude	Gyro Compasses				True Heading
				---- Gyro	-----Gyro			
				Gyro Reading	Error	Gyro Reading	Error	
10Mar94	1000	36°24 W	74°12 W	120	1.0E			121
	1012	36 04 W	074 14 W	270	1.0E			271
	1025	36 05 W	074 18 W	297	1.0E			

In this example the date, time, latitude, and longitude of the observation are noted. The master gyro is reading 120; the error determined by the morning azimuth is 1.0 E. Remember, if the compass is least the error is east; you would add the error to obtain the true heading. Knowing our true heading, we can now apply our variation and compare the magnetic compasses.

Variation	Magnetic Heading	Magnetic Compasses				DG ON/OFF	REMARKS
		Standard		Steering			
		Compass Reading	Dev	Compass Reading	Dev		
14 W	135	136	1W	134	1E	OFF	
14 W	285	289	4W	283	2E	OFF	Energized degaussing at 1022
14.5W		313		311		ON	

As you can see, this is the practical application of your newly acquired compass calculation skills. Practice by filling in the blanks for the 1025 entry. When under way, the compasses must be compared every one-half hour and at each course change.

Note: There is an exception; if a ship is in a formation and changing course frequently, or the ship is alongside another ship, each course change does not need to be recorded. Use the following statement in the Remarks column: "Steering various courses while alongside (in formation)." A comparison must still be made every one-half hour!

Magnetic Compass Adjustment

Background

The magnetic compass must be adjusted at least once a year. The process of adjustment is called "swinging ship." This is required as a safety precaution; also as the ship steams, its magnetic properties will change.

The process of swinging ship is too detailed and complicated to be completely taught within this training manual. As the magnetic compass is considered a piece of equipment, it is covered by the Planned Maintenance System (PMS). Training on compass adjustment is normally done by OJT.

Basics

The following table lists the basic steps to be followed to adjust a magnetic compass. *It cannot be used solely as a guide for compass adjustment.*

Rule: When performing actual adjustment, you must use the PMS card and publication 226.

Step	Action
1.	Meet with the navigator to schedule PMS.
2.	Twenty-four hours prior, inform QM gang of intentions.
3.	Four hours prior review MRC; gather all tools.
4.	Four hours prior, calculate the true courses to steer.
5.	Man all stations and begin swinging ship.
6.	Fill out a new magnetic compass deviation table.
7.	Have the new table signed by the commanding officer.

Closing

The process of swinging ship is often tedious and very time consuming. In most cases a minimum of 4 hours should be set aside for this task. It is not advisable to attempt to adjust a compass in moderate to heavy weather. Doing so will often render the results inaccurate.

ANSWERS

EX 1; 020; 088.5, 091.5; 211.5, 8.5 E; 3.0 W, 7.0 E.
EX 2; 4.0 W, 3.0 E, 2.0 E, 1.5 E.

The Gyrocompass

Introduction

The gyrocompass was developed as the answer to the need for an instrument that would indicate TRUE NORTH rather than MAGNETIC NORTH. The gyrocompass is now the main source for determining direction.

Operation

The basis for the gyrocompass is the **gyroscope**. A rapidly spinning body having three axes of angular freedom constitutes a gyroscope. This may be illustrated by the heavy wheel rotating at high speed in supporting rings or gimbals.

The gyrocompass must be lit off a minimum of 4 hours prior to use. This allows the gyro to warm up and settle. It is desirable to lite off the gyrocompass 24 hours prior to the scheduled underway time.

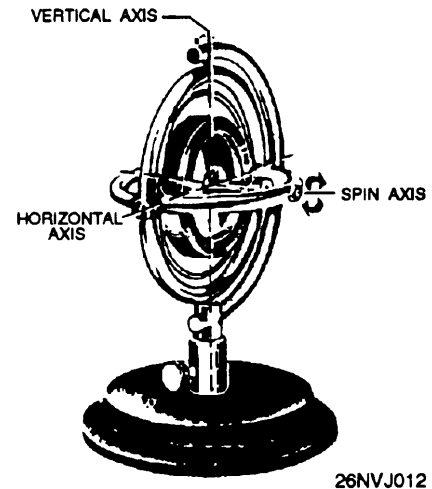


Figure 2-11. Gyroscope.

Components

The gyrocompass is powered by electricity and consists of two main components. They are the **master gyro** and **repeaters**. The master gyrocompass consists of a control cabinet, power supply, speed unit, alarm unit, and transmission units. It is normally located within the ship's hull where it is least affected by pitch, roll, yaw, and battle damage. The IC electricians are responsible for its upkeep.

Accuracy

A properly functioning gyrocompass will often have a mechanical error of 2° or less. The gyrocompass must be checked for error at least once daily while the ship is under way.

Repeaters

Purpose

Repeaters are designed to receive the signal transmitted from the master gyro. This allows the ship's control stations to receive real-time gyro data. The chief advantage of repeaters is that they may be set up nearly vertical for use by the helmsman. Repeaters may also be placed flat for taking bearings of nav aids or ships with alidades and bearing circles.

Figure 2-12 illustrates a standard repeater. The card is laid out with relative bearings on the outside circle and true bearings on the inside circle. In upcoming topics you will learn how to use related tools to measure angles (bearings) using repeaters.

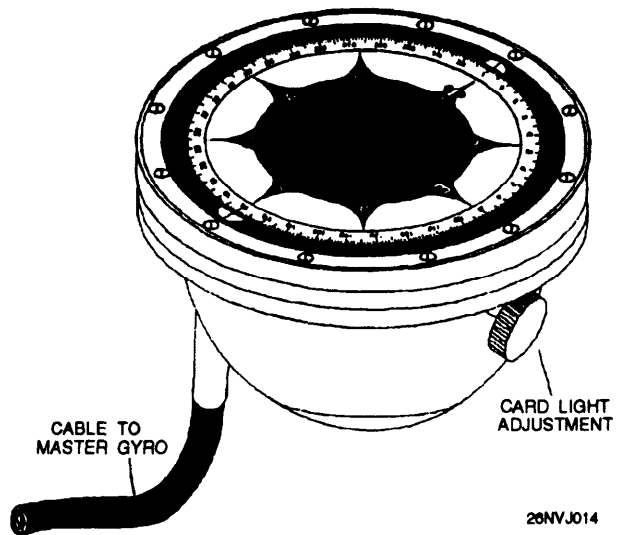


Figure 2-12. Standard gyro repeater.

Locations

Repeaters are normally found at all the ship's control stations, these areas include but are not limited to the following spaces:

- The pilothouse and bridgewings
- Aftersteering
- Secondary conn

Additional repeaters are normally placed in the following spaces:

- Commanding officer's stateroom
- CIC
- Navigator's stateroom

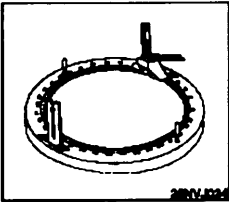
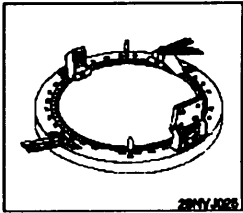
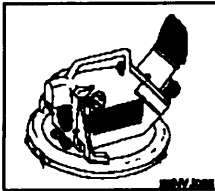
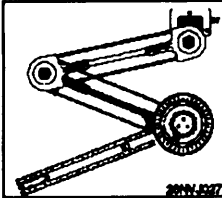
Accuracy

The QMOW must check the repeaters occasionally against the master gyro to determine errors.

Tools Used to Measure Direction

Introduction

The QM uses several pieces of navigational equipment to determine direction. Remember that direction may be labeled in many ways, such as course, *azimuth angle*, *bearing*... . The following table contains information about tools and their uses.

Tool	Most often used...
Bearing Circle	to obtain the bearings of other ships to determine relative motion also to find the bearing of any object. 
Azimuth Circle	to obtain an azimuth of the Sun for checking gyrocompass error also as a bearing circle. 
Telescopic Alidade	to obtain bearings of aids to navigation to determine the ship's position also to obtain data for ¹ amplitudes for checking gyrocompass error. 
Parallel Motion Protractor (PMP)	to determine and plot bearings and courses on charts 

¹ Obtaining an amplitude is a method of checking the error of the gyrocompass. An amplitude is normally taken of the Sun rising or falling, but it may be used for any celestial body.

Gyrocompass Error

Introduction

The gyrocompass is normally the main reference for direction for the surface navigator. When properly used, serviced, and maintained, the modern gyrocompass is extremely accurate. However, as is the case with all electronic instruments, it is subject to error and damage.

One power failure or other casualty can render the entire system useless. All naval ships are equipped with gyro failure alarms. The alarms sound when a loss of power is experienced. It is during this time that the magnetic compass comes into play. As you learned earlier, the magnetic compass does not require electricity to operate. It's always ready for use by the navigator.

Errors

Most normally functioning gyrocompasses will not have an error of more than 2.0° . More often than not, the error is between 0.0° and 0.5° .

Rule: When at sea, the Quartermaster **must** determine the gyrocompass error *at least once a day*. However, the prudent navigator will take advantage of every opportunity to check the accuracy of a gyro.

There are many methods of checking the accuracy of a gyrocompass. The following methods are commonly used on U.S. Navy ships:

- Terrestrial range
- Trial and error (Franklin technique)
- Azimuth of the Sun
- Amplitude of the Sun

The first two methods are used only when a ship is near land. They use aids to navigation and geographic locations shown on a chart for reference. The last two methods are used when the ship is at sea, and they use the Sun as a reference.

Next

Before we learn these methods, we have to learn how to use the bearing circle, alidade, and PMP. They play a large part in the first two methods. The last two methods use celestial navigation methods to determine error and will be discussed in length in the Celestial Navigation chapter.

Bearing Circle and Azimuth Circle

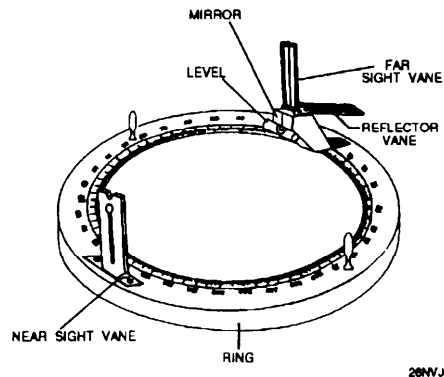


Figure 2-13. Parts of a bearing circle.

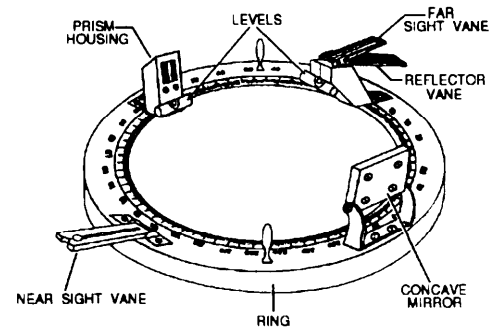


Figure 2-14. Parts of an azimuth circle.

Components

Figure 2-13 is a diagram of a bearing circle and figure 2-14 is a diagram of an azimuth circle. The table below lists the major parts and functions of each of these circles.

Part	Bearing Circle	Azimuth Circle	Function
Ring	Yes	Yes	Fits upon a 7 ½ inch gyro repeater.
Sight Vanes	Yes	Yes	Allow the observer to take bearings of objects by aligning the two vanes to the object. The near vane contains a peep sight while the far vane contains a vertical wire. The far vane is mounted on top of a housing that contains a reflective mirror inside enabling the observer to read the bearing from the reflected portion of the compass card.
Reflector Vanes	Yes	Yes	Allow the observer to observe azimuths of celestial bodies (stars and planets) at various altitudes by picking up their reflection in the black mirror. When the body is observed, its reflection appears behind the vertical wire in the far vane.
Levels	Yes	Yes	Indicate if the ring is level with the horizon. NOTE: Bearings read when the ring is not level are inaccurate.
Concave Mirror	NO	Yes	Reflects the Sun's rays onto the prism housing on the other side of the ring when the observer is taking an azimuth of the Sun.
Prism Housing	NO	Yes	Directs the beam of light from the concave mirror downward in a narrow beam onto the compass card enabling the observer to read the azimuth to the Sun.

How to Use a Bearing Circle

Follow the steps in the table to properly obtain a bearing.

Step	Action
1.	Place the ring on top of the repeater, then gently twist the handles to lock in place.
2.	Orient the bearing circle with the peep sight nearest to you and the far vane closest to the object to be sighted.
3.	Look through the peep sight and view the object inside the far vane.
4.	Rotate the bearing circle left or right to align the vertical wire in the far vane with the center of the object.
5.	Keep the bearing circle level by observing the spirit level.
6.	When the object is in line with the peep sight and wire, observe the bearing reflected from the mirror in the housing from the compass card.
7.	Determine which compass mark is aligned with the crosshair seen in the mirror, and read the bearing.

Note

Information concerning how to use the azimuth circle will be presented in the Celestial Navigation chapter.

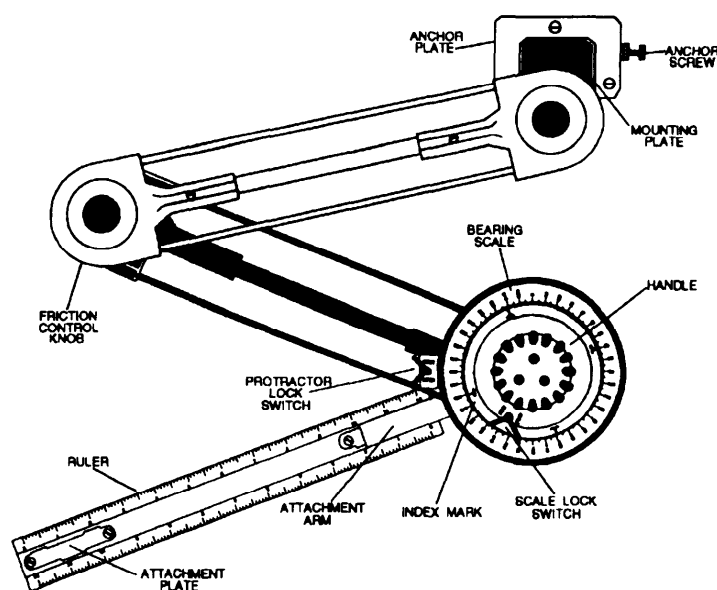
Parallel Motion Protractor (PMP)

Introduction

The PMP is a valuable tool for plotting direction quickly and accurately. When in restricted waters and plotting fixes every 3 minutes, you will greatly appreciate this instrument. The PMP is usually anchored to the top of the chart table.

The PMP is designed to keep the moveable compass rose oriented to the longitude and latitude of any chart. An arm is attached to the moveable compass rose which can be rotated to whatever bearing you require and then moved to the object on the chart that the bearing was taken to, so an LOP can be drawn.

Part	Description of function
Anchor plate	Allows the PMP to be attached to the chart table.
Friction control knob	Allows adjustment of movement of the arms at the two linkage points.
Bearing scale	A 360° circle marked in 1° increments. When locked it will maintain its orientation when moved around the chart table.
Index marks	Used to align the ruler on the desired bearing. The four marks spaced every 90° are inscribed on a plate that is directly linked to the handle and the ruler.
Protractor lock switch	Locks the bearing scale when aligning the PMP.
Scale lock switch	Locks the PMP ruler on a desired bearing.



281VJ020

Figure 2-15. Parts of a PMP.

How to Set Up the PMP

Note

The PMP is normally set up to automatically compensate for gyrocompass error. The error may be "dialed in"; this allows the LOPs and course lines to be plotted without correction.

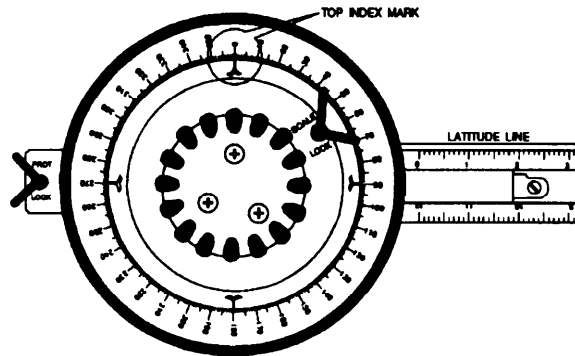
Follow these steps to set up the PMP. See figures 2-16 and 2-17 on the next page to see what the scale looks like with 0° gyro error and also with gyro error dialed in.

Step	Action	
1.	Tape the chart you are using onto the chart table by its comers.	
2.	Take the PMP out of its storage box.	
3.	Place the mounting plate inside the anchor plate and tighten the anchor screw to secure the PMP to the chart table.	
4.	Attach the ruler to the PMP by placing the ruler on the table and sliding it into the attachment arm.	
5.	Unlock both the protractor and the scale locks.	
6.	Twist the handle to align the ruler with the latitude line on the chart.	
7.	Rotate the bearing scale to the appropriate position.	
	IF gyro error is...	THEN align the scale . . .
	Zero	To the 0° index mark
	Westerly	To the index mark on the scale to the left of zero, equal to the amount of gyro error
	Easterly	To the index mark on the scale to the right of zero, equal to the amount of gyro error
8.	Lock the bearing scale using the protractor lock switch.	

How to Set Up the PMP, Continued

How to Align with 0° Error

Figure 2-16 illustrates how the PMP looks when it is aligned with no gyro error. The ruler is aligned on any parallel (latitude line) and the scale lock is released, the moveable compass rose is aligned as shown and the scale lock is tightened. The PMP is now aligned to true north and is ready to plot LOPs or courses.

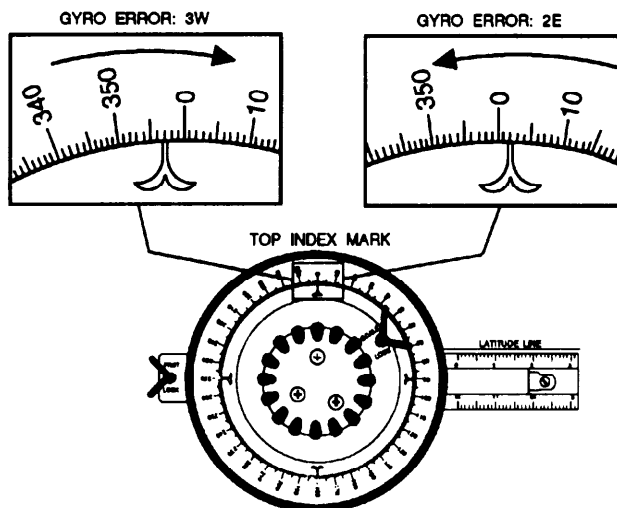


28NVJ021

Figure 2-16. PMP dialed in with 0° gyro error.

Aligning the PMP with Gyro Error

Figure 2-17 illustrates how the PMP looks when aligned with 30° W or 2° E gyro error. The ruler is aligned on any parallel (latitude line) and the scale lock is released, the moveable compass rose is aligned as shown, and the scale lock is tightened.



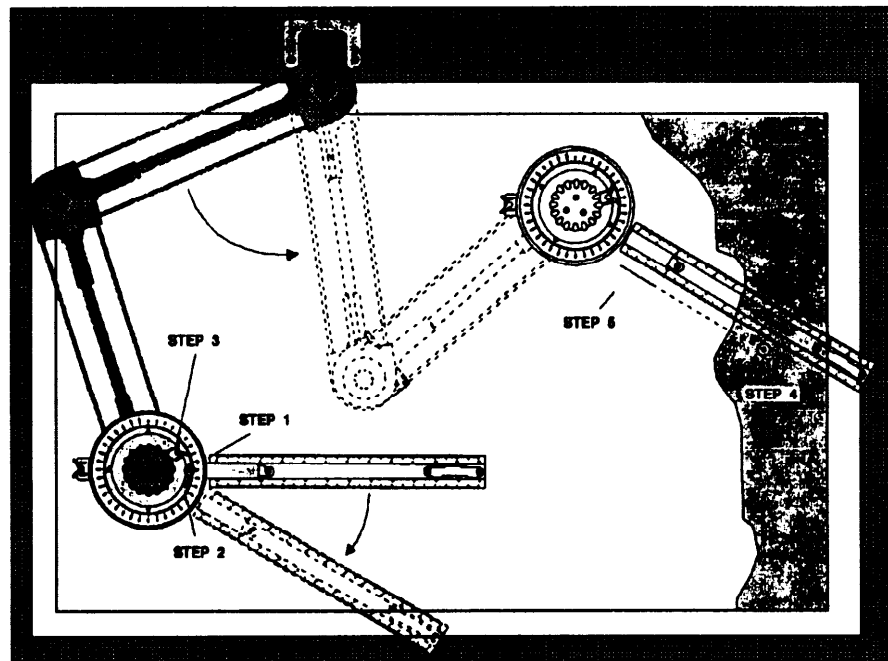
28NVJ022

Figure 2-17. PMP dialed in with gyro error.

How to Plot With a PMP

With the PMP properly aligned, its easy to use the tool to plot bearings or lay out course lines. Use the following steps and figure 2-18 to plot with a PMP.

Step	Action
1.	Locate the index mark closest to the ruler.
2.	Rotate the handle, which moves the index mark and ruler, so the index mark points to the bearing you want to plot.
3.	Maintain the index mark in that position by either locking the scale lock switch or holding the bearing scale and index mark plate tightly with your thumb and forefinger.
4.	Move the ruler to the charted object that you took a bearing to.
5.	Draw the line of position on the chart.



26NVJ023

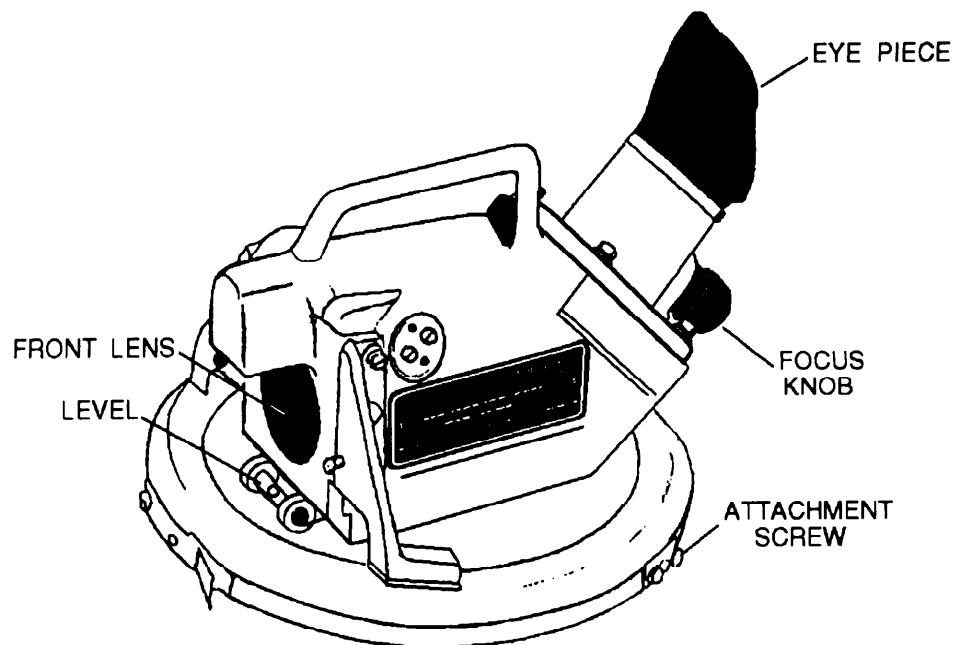
Figure 2-18. How to plot with a PMP.

Telescopic Alidade

Parts and Functions

The following are the parts and functions of the telescopic alidade shown in figure 2-19.

Part	Description of Function
Ring	Fits upon a 7½ inch gyro repeater.
Light filter knob	Enables the observer to switch to an internal light filter, which protects your eye from the brightness of the Sun.
Polarizing adjustment knob	Enables the observer to adjust the light filter from light to dark, depending on the brightness of the Sun.
Level	Indicates if the ring is level with the horizon. Bearings read when the circle is not level are NOT ACCURATE!
Focus knob	Enables the observer to adjust the internal telescope lens so the view is focused.



26NVJ019

Figure 2-19. Telescopic alidade.

How to Use the Telescopic Alidade

View Through the Alidade

The optical system simultaneously projects the image of the compass card, together with a view of the spirit level, onto the optical view of the telescope. By this means, both the object and its bearing can be viewed at the same time through the alidade eyepiece.

Figure 2-20 illustrates taking a visual bearing with a telescopic alidade. In this example, the bearing to the lighthouse is 022° .

Follow these steps to properly take a bearing with a telescopic alidade.

Step	Action
1.	Place the ring on top of the gyro repeater and twist locks into
2.	Point the front lens of the alidade towards the object to be sighted. Tip: Sight along the handle to quickly find an object.
3.	Look into the eyepiece and rotate the alidade right or left until the object is aligned with the crosshair.
4.	Keep the alidade level by observing the spirit level in the top part of the view.
5.	With the object lined up and level, read the bearing from the reflected compass card. Read the inside compass card for true bearings.

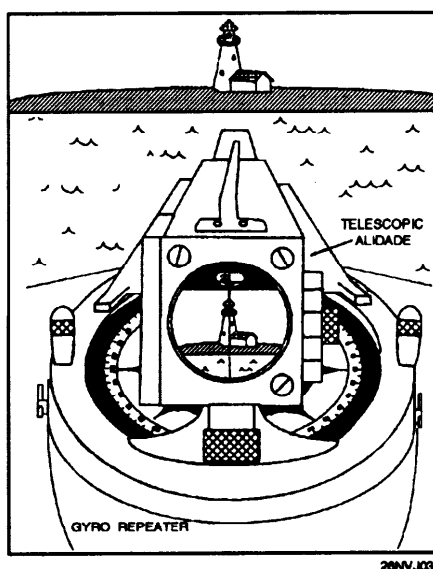
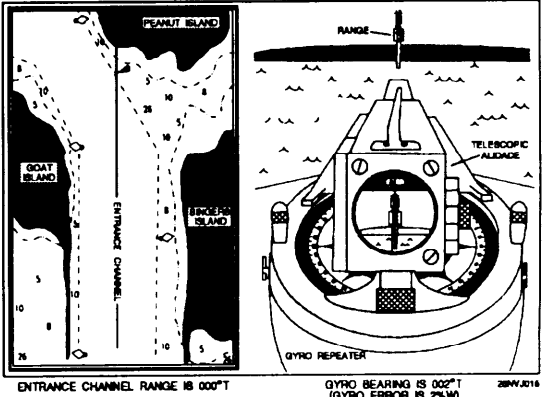


Figure 2-20. View through an alidade.

Determining Gyro Error by Terrestrial Range

Background

An excellent opportunity to check the accuracy of the gyrocompass presents itself each time a ship enters or departs port. Most harbors will have at least one set of range markers set. This method of checking a gyrocompass is often referred to as obtaining a *range of opportunity*. To determine gyro error by terrestrial range, you should follow the steps in the table and refer to figure 2-21.

Step	Action
1.	View the range markers through the alidade.
2.	The ship maneuvers "on range" (range markers are in line.)
3.	"Shoot" (take) a bearing on the range markers while they are lined up.
4.	Compare the bearing taken against the chart.  <p>ENTRANCE CHANNEL. RANGE IS 000°T GYRO BEARING IS 002°T (GYRO ERROR IS 2°W)</p>

Tip

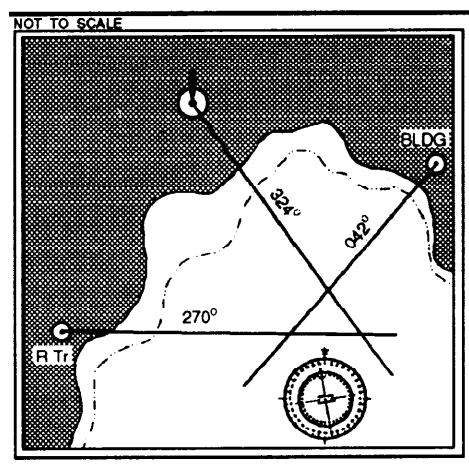
It is also possible to mark a range as it passes down the port or starboard side of the ship. The steps in the action table are still basically the same; the exception is that the ship will not maneuver on range. The bearing taker must shoot the bearing to the range markers the instant that they are in line. This method is only as accurate as the experience and ability of the bearing taker.

Determining Gyro Error by Trial and Error

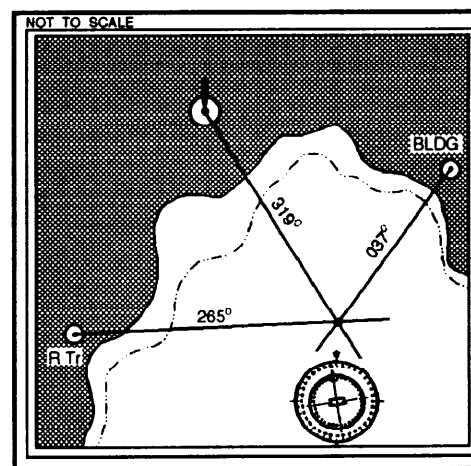
Franklin Technique

The Franklin technique is extremely useful just prior to getting a ship under way. The Franklin technique provides an alternative and **must** be used if the gyro error cannot be checked by another method prior to getting under way. To determine gyro error using the Franklin technique follow the steps in the table and refer to figure 2-22.

Step	Action
1.	Select three to five nav aids from the chart. For the best results, the selected nav aids should be about 120" apart. (The ship must be pierside or anchored, large towers and conspicuous buildings may be selected).
2.	Compare the repeater(s) to be used against the master gyro; note errors.
3.	Take a round of bearings on the selected nav aids, and apply any repeater error to the bearing. Example: The repeater reads 187° and the master gyro reads 187.5° . The repeater is reading $\frac{1}{2}^{\circ}$ less than (compass least error east). Since the error is 0.5° east (less than), 0.5 must be added to all bearings taken from that repeater.
4.	Plot the corrected bearings on the chart with the PMP set for 0° gyro error.
5.	Observe how the lines intersect, if they meet in a point the gyro is "ON" and has no error. If the lines do not intersect, subtract or add 1.0° at a time until the triangle closes. The amount of correction is the total gyro error. Log it in the deck log and Magnetic Compass Record Book.



ACTUAL BEARINGS TAKEN



BEARINGS ADJUSTED BY SUBTRACTING 5 DEGREES (GYRO ERROR = 5° W)

Figure 2-22. Determining gyro error by adjusting bearings.

